

**EXTENSIBLE FIBERS AND NONWOVENS MADE FROM LARGE DENIER
SPLITTABLE FIBERS**

Kelyn Anne Arora

5

Eric Bryan Bond

Michele Ann Mansfield

CROSS REFERENCE TO A RELATED PATENT

10 This application is a continuation application of prior copending International Application No. PCT/US02/06531, filed March 1, 2002, designating the U.S., which claims the benefit of U.S. Provisional Application No. 60/275,976, filed March 15, 2001.

FIELD OF THE INVENTION

15 The present invention relates to a method for making a soft nonwoven web with improved extensibility. Nonwoven webs with this combination of properties are particularly well suited for use in disposable absorbent articles such as diapers, incontinence briefs, training pants, feminine hygiene garments, wipes, and the like, as they are able to be used in portions of the article where extensibility, softness and abrasion resistance can aid in the article's comfort and overall 20 performance.

BACKGROUND

25 Nonwoven webs formed by nonwoven extrusion processes such as, for example, meltblowing processes and spunbonding processes may be manufactured into products and components of products so inexpensively that the products can be viewed as disposable after only one or a few uses. Representatives of such products include disposable absorbent articles, such as diapers, incontinence briefs, training pants, feminine hygiene garments, wipes, and the like.

30 There is an existing consumer need for nonwovens that can deliver softness and extensibility when used in disposable products. Softer nonwovens are gentler to the skin and help to provide a more garment-like aesthetic for diapers. Nonwovens that are capable of high extensibility at relatively low force can be used to provide sustained fit in products such as disposable diapers (i.e. as part of a stretch composite) and facilitate the use of various mechanical post-treatments such as stretching, aperturing, etc. Extensible materials are defined herein as those capable of elongating, but not necessarily recovering all or any of the applied strain. Elastic materials, on the

other hand, by definition, must recover a substantial portion of their elongation after the load is removed.

There are several approaches that have been used in the art to create extensible nonwovens:

5 WO 00/04215 (assigned to Fibervisions) defines a specific bond pattern designed to produce a high elongation nonwoven fabric, specifically for skin-core PP staple fibers. The bond pattern has sites in adjacent rows staggered such that they do not overlap one another in the MD. Preferably the sites are rectangular in shape and cover a total bond area of < 20%. It teaches that fibers at an angle of 35-55° from the MD will not be bonded and therefore allow for higher CD
10 elongation.

Fiber formulation is often used to achieve extensibility. For example, Fiberweb has 2 U.S. Patents that claim blends of PE and PP with and without a miscible ethylene-propylene copolymer that produce soft, strong nonwovens with low fuzz and good elongation (Nos. 5,804,286 & 5,921,973). Elastic and extensible composite fabrics are also claimed. Dow
15 Chemical also has filed for patents in this area, claiming PP/ethylene copolymer blends (WO 00/34385) and blends of 2 different ethylene polymers (U.S. No. 6,015,317) for improved bonding and fabric elongation while maintaining good spinning performance. U.S. Patent No. 5,616,412 (assigned to DuPont) claims filaments (2-4 dpf) of PP and higher MW polystyrene that exhibit higher elongation (>700%) vs. filaments comprising only PP. Exxon has 2 patents aimed
20 at delivering soft nonwovens with good elongation claiming ethylene copolymers (U.S. Patent No. 5,322,728) and ethylene acrylic copolymers (U.S. Patent No. 4,769,279). Exxon also has 2 patents for extensible meltblown nonwovens comprising a blend of polyolefin and elastomeric copolymer of an isoolefin and conjugated diolefin, e.g., isobutylene-isoprene copolymer (U.S. Patent Nos. 4,804,577 & 4,874,447). U.S. Patent No. 5,349,016 (assigned to Himont) claims drawn fibers of grafted propylene polymers (e.g. styrene or methyl methacrylate grafted onto PP backbone) that have higher bend recovery and modulus, and in some cases elongation (~50-60% increase over PP control). U.S. Patent No. 6,080,818 (assigned to Huntsman) claims fibers for nonwovens comprising a blend of isotactic PP and an atactic flexible polyolefin that have higher elongation than if the flexible polymer was not included.
25

30 All of these approaches can increase fiber extensibility to some degree, but they also involve the use of higher-cost materials and can involve special mixing requirements to ensure proper dispersion within the blends.

The way in which the nonwoven web is formed can also be used to maximize stretch properties. In U.S. Patent No. 5,494,736 (assigned to Fiberweb) a high elongation carded

nonwoven (HEC) from high elongation fibers are laid down to be more CD oriented than conventional carded fabrics. Bond areas claimed are in the range of 8-25%.

Splittable multicomponent fibers were developed with the objective of forming very fine (e.g. subdenier) fibers. It is well known to be difficult to spin filaments having sizes less than 2
5 denier per filament. By spinning splittable or fibrillatable multicomponent fibers, this difficulty can be overcome. Fine denier fibers are desirable in a fabric for softness, filtration or barrier properties. Of the many patents in the art on splittable multicomponent fibers, the objective is almost always to produce the finest fibers possible. Typically, 2-3 dpf (15-25 micron) multicomponent fibers are spun, and then split by some means into a multitude of smaller fibers.
10 Many methods for splitting fibers have been developed, including hydroentangling, chemical treatments, aqueous treatments, thermal treatments, needling, stretching, and various other mechanical treatments. Certain polymers that are sufficiently dissimilar can split spontaneously upon fiber formation or drawing. Cross-sections that have been used include side-by-side, segmented pie, hollow segmented pie, islands-in-the-sea, segmented ribbon, and tipped
15 multilobal. Many other unique fiber shapes and cross-sections have also been developed to meet specific needs or to improve the efficiency of splitting.

Non-splittable multicomponent fibers have been used for the purpose of increasing fiber and/or fabric extensibility. One approach is to use an elastic component in combination with an inelastic component. This approach has the drawback of using a relatively expensive elastic
20 material, which can also have a tacky feel unless it is completely surrounded by the non-elastic component. Another approach is to use cross-sections that lead to crimped fibers. The crimp in these fibers, however, can only provide limited amounts of extensibility.

There exists within the industry today an unmet need for extensible nonwovens with moderate to low denier fibers that can be made from conventional thermoplastic resins without
25 the need for high cost specialty polymers or elastic polymers. It is well known that as spinning speeds increase, molecular orientation increases and fiber elongation decreases. For strong, low denier fibers, this is not a problem, but producing low denier fibers with high elongation remains a significant challenge. It is therefore an object of the present invention to produce fibers (and nonwovens made from such fibers) that have high elongation to break at moderate to low fiber
30 diameters. This is accomplished by spinning splittable multicomponent fibers under appropriate conditions to produce large diameter, low orientation fibers which can then be split into smaller segments that maintain the properties of the parent fiber. Thus, fibers are produced having elongations significantly higher than if a fiber of that same size had been spun directly.

It is a further object of the present invention to produce extensible nonwovens made from
35 fibers having a high elongation to break at moderate to low fiber diameters.

It is a further object of the present invention to produce disposable absorbent articles comprising extensible nonwovens made from fibers having a high elongation to break at moderate to low fiber diameters.

5

SUMMARY OF THE INVENTION

The present invention provides fibers (e.g. for nonwovens) that have high elongation to break at moderate to low fiber diameters. This is accomplished by spinning splittable composite fibers, comprising at least two thermoplastic resin components, under appropriate conditions to produce large diameter, low orientation fibers which can then be split into smaller segments that 10 maintain the properties of the parent fiber. Thus, fibers are produced having elongations significantly higher than if a fiber of that same size had been spun directly.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1: Schematic drawings of fiber cross-sections suitable for use in the fibers of the 15 present invention

Figure 2: Optical micrograph of fiber cross-section of a 50/50 PP/HDPE 16-segment pie fiber

Figure 3: Optical micrograph of fiber cross-section of a 50/50 PP/PET 16-segment pie fiber

20 Figure 4A: Optical micrograph of an as-spun fiber of 50/50 PP/PET

Figure 4B: Optical micrograph the same 50/50 PP/PET fiber as in Figure 5A that has been split under tension

Figure 5: Optical micrograph of fiber cross-section of an 80/20 PP/PVOH 16-segment pie fiber

25

DEFINITIONS

As used herein, the term "absorbent article" refers to devices that absorb and contain body exudates, and, more specifically, refers to devices that are placed against or in proximity to the 30 body of the wearer to absorb and contain the various exudates discharged from the body.

The term "disposable" is used herein to describe absorbent articles that are not intended to be laundered or otherwise restored or reused as an absorbent article (i.e., they are intended to be discarded after a single use and, preferably, to be recycled, composted or otherwise disposed of in an environmentally compatible manner). A "unitary" absorbent article refers to absorbent articles

that are formed of separate parts united together to form a coordinated entity so that they do not require separate manipulative parts like a separate holder and liner.

As used herein, the term "nonwoven web", refers to a web that has a structure of individual fibers or threads which are interlaid, but not in any regular, repeating manner.

- 5 Nonwoven webs have been, in the past, formed by a variety of processes, such as, for example, air laying processes, meltblowing processes, spunbonding processes and carding processes, including bonded carded web processes.

As used herein, the term "microfibers" refers to small diameter fibers having an average diameter not greater than about 100 microns, and a length-to-diameter ratio of greater than about

- 10 10. Those trained in the art will appreciate that the diameter of the fibers comprising a nonwoven web impact its overall softness and comfort, and that the smaller denier fibers generally result in softer and more comfortable products than larger denier fibers. For fibers of the present invention, it is preferable that the diameters are in the range of about 5 to 25 microns to achieve suitable softness and comfort, more preferable in the range from about 10 to 25 microns in diameter, and even more preferable in the range from about 10 to 20 microns in diameter.

As used herein, the term "meltblown fibers", refers to fibers formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into a high velocity gas (e.g., air) stream which attenuates the filaments of molten thermoplastic material to reduce their diameter, which may be to a microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly dispersed meltblown fibers.

As used herein, the term "spunbonded fibers" refers to small diameter fibers that are formed by extruding a molten thermoplastic material as filaments from a plurality of fine, usually circular, capillaries of a spinneret with the diameter of the extruded filaments then being rapidly reduced by drawing using conventional godet winding systems or through air drag attenuation devices. If a godet system is used, the fiber diameter can be further reduced through post extrusion drawing.

As used herein, the terms "consolidation" and "consolidated" refer to the bringing together of at least a portion of the fibers of a nonwoven web into closer proximity to form a site, or sites, which function to increase the resistance of the nonwoven to external forces, e.g., abrasion and tensile forces, as compared to the unconsolidated web. "Consolidated" can refer to an entire nonwoven web that has been processed such that at least a portion of the fibers are brought into closer proximity, such as by thermal point bonding. Such a web can be considered a "consolidated web". In another sense, a specific, discrete region of fibers that is brought into close proximity, such as an individual thermal bond site, can be described as "consolidated".

Consolidation can be achieved by methods that apply heat and/or pressure to the fibrous web, such as thermal spot (i.e., point) bonding. Thermal point bonding can be accomplished by passing the fibrous web through a pressure nip formed by two rolls, one of which is heated and contains a plurality of raised points on its surface, as is described in the aforementioned U.S. Pat.

- 5 No. 3,855,046 issued to Hansen, et al.. Consolidation methods can also include, but are not limited to, ultrasonic bonding, through-air bonding, resin bonding, and hydroentanglement. Hydroentanglement typically involves treatment of the fibrous web with high pressure water jets to consolidate the web via mechanical fiber entanglement (friction) in the region desired to be consolidated, with the sites being formed in the area of fiber entanglement. The fibers can be
10 hydroentangled as taught in U.S. Pat. Nos. 4,021,284 issued to Kalwaites on May 3, 1977 and 4,024,612 issued to Contrator et al. on May 24, 1977, both of which are hereby incorporated herein by reference.

Although the nonwoven web of the present invention can find beneficial use as a component of a disposable absorbent article, such as a diaper, its use is not limited to disposable
15 absorbent articles. The nonwoven web of the present invention can be used in any application requiring, or benefiting from, softness and extensibility, such as wipes, polishing cloths, furniture linings, durable garments, and the like.

The extensible, soft nonwoven of the present invention may be in the form of a laminate. Laminates may be combined by any number of bonding methods known to those skilled in the art
20 including, but not limited to, thermal bonding, adhesive bonding including, but not limited to spray adhesives, hot melt adhesives, latex based adhesives and the like, sonic and ultrasonic bonding, and extrusion laminating whereby a polymer is cast directly onto another nonwoven, and while still in a partially molten state, bonds to one side of the nonwoven, or by depositing melt blown fiber nonwoven directly onto a nonwoven. These and other suitable methods for making
25 laminates are described in U.S. Patent 6,013,151, Wu et al., issued January 11, 2000, and U.S. Patent 5932, 497, Morman et al., issued August 3, 1999, both of which are incorporated by reference herein.

As used herein, the term "polymer composition" generally includes, but is not limited to, homopolymers, copolymers, such as, for example, block, graft, random and alternating
30 copolymers, terpolymers, etc., and blends and modifications thereof. Furthermore, unless otherwise specifically limited, the term "polymer composition" shall include all possible geometrical configurations of the material. These configurations include, but are not limited to, isotactic, syndiotactic and random symmetries. Examples of suitable thermoplastic polymers for use in the present invention include, but are not limited to polyethylene, polypropylene,
35 polyethylene-polypropylene copolymers, polyvinyl alcohol, polyesters, nylon, polylactides,

polyhydroxyalkanoates, aliphatic ester polycondensates, and mixtures thereof. Preferred polymer compositions comprise polyolefins such as polyethylene and polypropylene, or polyesters such as poly(ethylene terephthalate) and copolymers thereof. Preferred additional polyesters include, but are not limited to, poly(lactic acid) (e.g., Lacea from Mitsui Chemicals, or EcoPLA from Dow Cargill), poly(caprolactone) (e.g., Tone P787 from Union Carbide), poly(butylene succinate) (e.g., Bionolle 1000 series from Showa Denko), poly(ethylene succinate) (e.g., Lunare SE from Nippon Shokubai), poly(butylene succinate adipate) (e.g., Bionolle 3000 series from Showa Denko), poly(ethylene succinate adipate), aliphatic polyester-based polyurethanes (e.g., Morthane PN03-204, PN03-214, and PN3429-100 from Morton International), copolymers of adipic acid, terephthalic acid, and 1,4-butanediol (e.g., Eastar Bio from Eastman Chemical Company, and Ecoflex from BASF), polyester-amides (e.g., BAK series from Bayer Corporation), hydrolyzable aromatic/aliphatic copolymers (e.g., Biomax from DuPont), cellulose esters (e.g., cellulose acetate, cellulose acetate butyrate, and cellulose acetate propionate from Eastman Chemical Company), combinations and copolymers thereof, and the like.

The polymer compositions may further include various non-polymeric components including, among others, nucleating agents, antiblock agents, antistatic agents, slip agents, pro-heat stabilizers, antioxidants, pro-oxidant additives, pigments, fillers and the like. These additives may be employed in conventional amounts although, typically, such additives are not required in the composition in order to obtain the advantageous combination of softness and extensibility.

One skilled in the art will appreciate that the melt flow rate of the polymer composition is suitable for the fiber producing method of interest, for example, melt spinning or melt blowing. The melt flow rate of a polymer composition can be determined using, for example, the methods outlined in ASTM D1238.

As used herein, the term "extensible" refers to any fiber, which, upon application of a biasing force, is elongatable to at least about 200 percent without experiencing catastrophic failure, more preferable to at least 400 percent elongation without experiencing catastrophic failure, and even more preferable to at least 800 percent elongation without experiencing catastrophic failure. The percent elongation to break can be determined using, for example, the method outlined in ASTM D3822, and is defined as the expanded length at break minus the initial test gauge length divided by the initial test gauge length multiplied by 100.

The fibers of the present invention are multicomponent in structure. Component, as used herein, is defined as a separate part of the fiber that has a spatial relationship to another part of the fiber. The term multicomponent, as used herein, is defined as a fiber having more than one separate part in spatial relationship to one another. The term multicomponent includes bicomponent, which is defined as a fiber having two separated parts in a spatial relationship to

one another. The different components of multicomponent fibers are arranged in substantially distinct regions across the cross-section of the fiber and extend continuously along the length of the fiber.

As used herein, the diameter of a noncircular cross section fiber is the equivalent diameter
5 of a circle having the same cross-sectional area.

Spunbond structures, staple fibers, hollow fibers and shaped fibers such as multi-lobal fibers can all be produced using the present invention. The fibers of the present invention may have different geometries that include round, elliptical, star shaped, rectangular, and other various eccentricities. In this case, the multicomponent fibers of the present invention are splittable fibers
10 and may have the configurations such as side-by-side, ribbon, segmented pie, etc. Rheological, thermal and solidification differential behavior can potentially cause splitting. Splitting may also occur by a mechanical means such as ring-rolling, stress or strain, use of an abrasive, or differential stretching, by fluid induced distortion, such as hydrodynamic or aerodynamic and/or by any other suitable means.
15

DETAILED DESCRIPTION OF THE INVENTION

This invention provides a method for producing fibers with high extensibility. This is accomplished by using splittable composite fibers, comprising at least two thermoplastic resin components. Potential cross-sections that could be used include, but are not limited to: side-by-
20 side, segmented pie, hollow segmented pie, segmented ribbon, tipped multilobal, etc. The fiber cross-section may have any number of segments greater than one, and the fiber need not be round (options include but are not limited to round, elongated, multilobal, etc.). Examples of fiber cross-sections suitable for use in the present invention are illustrated in Figure 1. The splittable fibers may be composed of any 2 different thermoplastic resin materials. Preferred thermoplastic
25 resin components include, but are not limited to polyolefins, polyesters, polyamides, and mixtures thereof. The only requirement for the combination of resins used is that they are capable of separating from one another by some means. Potential combinations of polymers suitable for splitting include but are not limited to: polypropylene and polyethylene, polypropylene and polyesters, polyethylene and polyesters, polypropylene and nylon, polyethylene and nylon, etc.
30

By the method of the present invention, splittable composite fibers comprising at least two thermoplastic resin components are spun under conditions such that the fibers have relatively low molecular orientation and relatively large (e.g. > 40 microns) diameters. This could be accomplished, for instance, by not subjecting the filaments to large drawing forces commonly used to reduce fiber diameter, or by increasing the throughput per hole in the spinneret. Fibers are
35 typically drawn to diameters of 20 microns or less in order to increase the fiber strength and

reduce diameter for a softer tactile feel in, for example, a nonwoven fabric. This process, however, increases molecular orientation, which directly results in a decrease in elongation to break of the fibers. In the present invention, however, relatively large fibers are produced, which have relatively low molecular orientation. Because of this, the fibers also have high elongational properties.

After spinning, the fibers may be split apart into multiple segments. Alternatively, the fibers may be formed into a nonwoven fabric (e.g. spunbond, carded or meltblown) prior to splitting. The nonwoven fabrics may be bonded by any means known in the art, including but not limited to thermal point bonding, through-air bonding, ultrasonic bonding, hydroentangling, etc.

10 Through-air bonding, for example, can be used in combination with fibers of the present invention to provide a high loft, extensible nonwoven fabric.

The fabric may then be subjected to an appropriate treatment (e.g. mechanical, chemical, thermal) to induce splitting of the fibers. Rheological, thermal and solidification differential behavior can potentially cause splitting of the multicomponent fibers into their individual segments. Splitting may also occur by a mechanical means such as ring-rolling, stress or strain, use of an abrasive, or differential stretching, by fluid induced distortion, such as hydrodynamic or aerodynamic and/or by any other suitable means. One particularly preferred method to induce splitting fibers is ring-rolling. Ring-rolling is a preferred method for increasing softness, texture and extensibility of a nonwoven substrate. The incremental stretching that occurs during the ring-rolling process acts to split a significant portion of the multicomponent fibers in the nonwoven web.

Splitting of the large multicomponent fibers of the present invention does not significantly alter the properties (e.g. orientation, crystallinity) of the polymers within the fiber. Therefore, after splitting, the resulting fibers are smaller in diameter than the parent fiber but retain much of the same mechanical properties (e.g. high elongation). These fibers have higher elongation than would fibers of similar diameter that were formed directly by spinning and drawing. The parent multicomponent fiber of the present invention may be of any diameter large enough to produce the desired result, but is preferably greater than 40 microns.

Nonwoven fabrics of the present invention may be used in applications such as diapers, incontinence briefs, training pants, feminine hygiene garments, wipes, and the like. For example, they may be used in a laminate form as a diaper outer cover or in elastic laminates.

One example of a suitable process for making the composite fibers and the nonwoven fabrics made therewith of the present invention is described in U.S. Patent No. 5,482,772, Strack et al., issued on January 9, 1996, and incorporated herein by reference.

METHODS

Fiber spinning procedure

Neat or compounded materials are melt spun into bicomponent fibers using a two
5 extruder system, where each extruder is a horizontal single-screw extruder having a 0.5 inch
constant taper screw (3:1 compression ratio) and a 24:1 length-to-diameter ratio (Wayne Machine
& Die Company, Totowa, NJ). The extrudate rate from each extruder to the spinpack is
controlled by a 0.066 cubic centimeter per revolution metering melt pump (Parker Hannifin
Corporation, Zenith Pumps Division, Sanford, NC) that feeds a 4-hole spin pack (Hills
10 Incorporated, W. Melbourne, FL). The spinpack is fitted spinnerets and distribution plates for the
desired cross-section (e.g. sheath-core, hollow 16- segment pie, etc.). In addition, the
extruder/melt pump/spinpack system is mounted on an adjustable height a platform.

The molten filaments exit the spinneret into a quench cabinet that is located directly
below the spinpack and that can be varied in length from 24 to 72 inches, and are drawn down
15 with a height adjustable air drag device that uses compressed air at high pressures to produce a
stream of air that surrounds and draws the filaments, where the air drag devices are generally
either a type 901 or a type 909 Transvector® air flow amplifier (Vortec Corporation, Cincinnati,
OH). The extruder output is kept relatively constant at about 0.8 grams per minute per hole),
while the distance between the spinneret and the air gun, the distance between the air gun and the
20 collection box, as well as the extruder and spinpack temperatures are varied to achieve the desired
fiber diameters and cross-sections. A range of fiber diameters is collected by varying the air gun
inlet pressure and the air gun type.

Monofilament Tensile Test

Single fibers are tested according to ASTM standard D3822 except a strain rate of 200
25 %/min is used. Testing is performed on an MTS Synergie 400 tensile testing machine with a 10
N load cell and pneumatic grips. Tests are conducted at a rate of 2 inches/minute on samples with
a 1-inch gage length. Samples are pulled to break. Peak stress and % elongation at break are
recorded and averaged for 10 specimens.

30

Calculation of Equivalent Diameters for Fiber Segments

The equivalent diameter for each segment of component 1 (d_{s1}) in the fiber cross-section
is calculated as follows:

$$A_T = F_p \frac{\pi d_f^2}{4}$$

where A_T is the total area of polymer in the fiber cross-section, F_p is the fraction of the fiber cross-section occupied by polymer (total minus the hollow center), and d_f is the outer diameter of the fiber. The cross-sectional area of each segment of component 1 (A_1) is then calculated according

5 to:

$$A_1 = \frac{A_T X}{n}$$

where X is the fraction of component 1 in the fiber and n is the number of component 1 segments in the fiber (8 in the case of a 16-segment pie fiber).

The equivalent diameter of each segment of component 1 (d_{s1}) is then calculated by:

$$10 \quad d_{s1} = \left(\frac{4A_1}{\pi} \right)^{0.5}$$

The following examples illustrate the practice of the present invention but are not intended to be limited thereof.

15 EXAMPLES

The following non-limiting examples are illustrative of splittable, extensible multicomponent fiber configurations of the present invention. All percentages, ratios and proportions used herein are by weight percent, unless otherwise specified.

20 Comparative Example 1:

100% polypropylene fibers were produced using Basell ProFax PH835 as the polypropylene resin. A mass throughput of 0.85 grams/hole/minute and a melt temperature of 220 °C were used. At a spinning speed of 500 m/min, the fibers had a diameter of 50 microns and an elongation at break of 790%. These fibers have the desired high elongation but are too large to produce the desired softness and uniformity in a nonwoven fabric.

Comparative Example 2:

Fibers were made under the same conditions as described in Comparative Example 3, except the air jet pressure was adjusted to produce a spinning speed of 3800 m/min. The resulting

fibers have a diameter of 18 microns and an elongation to break of 181%. These fibers have the desired low diameters but do not have high elongation.

Example 1: Polypropylene/High Density Polyethylene fibers

5 Hollow 16-segment pie fibers were spun from polypropylene and polyethylene using a mass throughput of 0.8 grams/hole/minute. The polypropylene resin used was ProFax PH835 from Basell Polyolefins and the polyethylene resin was DMDA-8920 high-density polyethylene, obtained from Dow Chemical Company. Polypropylene/polyethylene ratios of 90/10 and 50/50 were produced over a range of spinning speeds each. A cross-section of a 50/50 fiber is shown in
10 Figure 2. As spun, the fiber cross-sections are intact, but upon application of force (e.g. tension or shear), they are split into 16 segments of significantly smaller diameter than the parent fiber. Data for several of these fibers is shown in Table 1 and demonstrates that small diameter fibers can be produced having higher elongation than if fibers of the same materials were spun directly to equivalent diameters.

15

Example 2: Polypropylene/Polyethylene terephthalate fibers

Hollow 16-segment pie fibers were spun from polypropylene and polyethylene terephthalate (PET) similarly to example 1. Achieve 3854 polypropylene from Exxon Chemical Company and F614C from Eastman Chemical Company were used. Polypropylene/PET ratios of
20 50/50 and 80/20 were produced. A cross-section of a 50/50 fiber is shown in Figure 3. Data for several of the fibers is shown in Table 1 and demonstrates that small diameter fibers can be produced having higher elongation than if fibers of the same materials were spun directly to equivalent diameters. As in Example 1, the fibers are not significantly split as spun, but splitting
25 can be readily induced by, for example, applying a tensioning force less than is required to break the fiber. Figure 4A is an optical micrograph of a 50/50 PE/PET fiber as it appears directly after spinning. Figure 4B is an optical micrograph of the same fiber after it was pulled in tension (not to break). The fibers readily split into multiple small fibers.

Example 3: Polypropylene/Polyvinyl alcohol

30 Hollow 16-segment pie fibers were spun from polypropylene and polyvinyl alcohol. Resins used were ProFax PH835 polypropylene and Vinex 2019 polyvinyl alcohol (PVOH) from Air Products. PP/PVOH ratios of 50/50 and 80/20 were produced. Figure 5 shows an optical micrograph of the cross-section of an 80/20 PP/PVOH fiber. Fiber diameter and elongation data is given in Table 1 and further illustrates that small diameter fibers with high elongation can be
35 produced. Since PVOH is water-sensitive, the fiber segments can be separated either by splitting

the fibers or by dissolving away the PVOH component to leave behind only the PP fiber segments with high elongation to break as compared to direct spun fibers.

Example 4: Polypropylene/Poly(lactic acid) fibers

5 Hollow 16-segment pie fibers were spun from polypropylene and polylactic acid (PLA). Resins used were ProFax PH835 polypropylene from Basell Polyolefins and Biomer L9000. PP/PLA ratios of 50/50 and 90/10 were produced. These fibers are easily split apart into PP and PLA fiber segments. Fiber diameter and elongation data are given in Table 1 and further demonstrate that small diameter PP fibers can be produced having high elongation to break.

10

Example 5: Polypropylene/Nylon 6 fibers

Hollow 16-segment pie fibers were spun from polypropylene and nylon 6. ProFax PH835 polypropylene from Basell Polyolefins and nylon 6 (purchased from Sigma-Aldrich, Catalog Number 18,111-0) were used as the two component resins. Polypropylene/nylon ratios of 50/50 and 80/20 were produced. These fibers are easily split into PP and nylon fiber segments.

Table 1: Fiber Data for 16-segment pie splittable fibers containing polypropylene

Example	Fiber Type	Parent Fiber Diameter (microns)	Polypropylene Segment Diameter (microns)	Elongation to Break (%)
C1	PP Monofilament	50	50	790
C2	PP Monofilament	18	18	181
1A	50/50 PP/HDPE	40	9	797
1B	90/10 PP/HDPE	47	14	763
2A	50/50 PP/PET	62	15	677
2B	80/20 PP/PET	56	16	756
3A	50/50 PP/PVOH	97	24	821
3B	80/20 PP/PVOH	43	13	657
4	90/10 PP/PLA	60	18	629

Example 6: Splittable Fibers Comprising Polyethylene

The fibers of examples 2-5 could also be repeated using polyethylene in place of the polypropylene component. For example, a linear low-density polyethylene such as Aspun 6811A from Dow Chemical Company could be used. The use of polyethylene would further enhance the softness and extensibility of fibers and nonwovens compared to polypropylene.

5 All documents cited in the Detailed Description of the Invention are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present invention.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and
10 modifications can be made without departing from the spirit and scope of the invention. It is intended to cover in the appended claims all such changes and modifications that are within the scope of the invention.